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USER'S GUIDE ON LIGHTING MANAGEMENT

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CONTENTS

Page

Chapter 1

INTRODUCTION

Lighting management is the judicious use of electric lighting to provide the ability to see. Many factors affect visibility. While light is obviously required to see, the intensity of light is only one factor affecting visibility. Other factors include the direction of the light, the uniformity of the light, the contrast of the task (what you are looking at), the size of the task, how long the task is looked at, etc. Prudent lighting management must strike a sound balance between the factors affecting resources (depletion of fossil fuels through electric use and monetary costs) and benefits (visibility affecting productivity, safety, and security).

Lighting management can be accomplished by a variety of different measures. The purpose of this Users' Guide is to provide you with a better awareness of these measures. With this knowledge, you will be in a better position to determine which measures provide the most cost effective alternatives for managing the elctric lighting at your activity.

This Users' Guide covers:

- An overview and checklist of measures to better manage and conserve electricity used for lighting.

- Specific implementation information on each of the lighting management measures.

- An inexpensive action plan which can systematically provide the desired quantity and quality of illumination at the lowest cost.

- The use of standards and independent testing laboratory reports to assess the potential benefits and pitfalls of new energy conserving products.

Chapter 2

OVERVIEW

Most of the lighting systems in Navy facilities have been designed to provide adequate (and in many cases more than adequate) visibility. The primary purpose of lighting management, then, is to reduce to the energy consumption (and operating costs) of these lighting systems while maintaining adequate visibility.

Energy is the product of power and operating time. To reduce the electrical consumption of lighting systems, either the power used or the operating time must be reduced.

There are only two ways to reduce lighting power requirements:

- Reduce light levels
- Improve lighting system efficiency

Also, there are only two ways to reduce lighting operating time:

- Turn off the lights when a room is not occupied
- Turn off the lights when a room has sufficient daylight

Many people have a fear that lighting management programs (or energy conservation programs) will result in less light. However, notice that only one of these four general energy conservation measures results in a reduction of light intensity levels.

2.1 REDUCE LIGHT LEVELS

Lighting intensities shall be in accordance with Department of Defense (DOD) 4270.1-M, "Department of Defense Construction Criteria Manual" (Ref 1) (see excerpt in Appendix A), and the "IES Lighting Handbook" (Ref 2). For each type of workspace, the "IES Lighting Handbook" provides a range of illumination values, whereas DOD 4270.1-M provides a single value. Generally, the DOD 4270.1-M single value corresponds to the Illuminating Engineering Society (IES) minimum value. For example, general office lighting is IES illumination category E (50 to 100 footcandles), and DOD 4270.1-M gives 50 footcandles. When the "IES Lighting Handbook" is consulted for types of workspaces not covered in DOD 4270.1-M, the minimum value of the appropriate illumination category should be used.

Workspaces designed to previous standards may have excessive light levels. Reduction of light levels to current standards will not reduce productivity provided the other factors that affect visibility (primarily direction of light) are satisfactory. In fact, by using nonuniform lighting reduction techniques (task-ambient lighting), it is often possible to simultaneously reduce average light levels and increase visibility.

2.2 IMPROVE LIGHTING SYSTEM EFFICIENCY

Ideally, lighting system efficiency should be defined in terms of visibility per watt of power. Unfortunately, there is no accepted way to define visibility. Illumination (quantity of lighting) is used instead of visibility simply because it is easy to measure. If there is sufficient illumination as defined by current standards, and there are complaints about insufficient lighting, the problem almost always is with other factors that contribute to good visibility. These factors are often called the "quality of illumination." The primary factor is the direction of the light relative to the task. For further information on these factors, see the Applications Volume, index item "Quality of Illumination," of Reference 2.

2.3 TURN OFF LIGHTS IN UNOCCUPIED SPACES

Lights are left on in unoccupied spaces generally for two reasons: (1) nobody thinks to turn them off; or (2) if they do think about it, they may be under the misconception that the act of turning lights off and on either wastes energy or shortens lamp life. Unfortunately, the second reason tends to condition the response of individuals towards the bad habit of leaving lights on (reason number 1). However, testing of lights has shown that they only have to be turned off for 1 second to save the amount of energy expended by the inrush current when the lights are turned on again. Detailed economic studies of tradeoffs between fluorescent lamp replacement and electrical costs have shown that any time a room is to be vacated for more than a couple of minutes, the lights should be turned off. Therefore, always turn off incandescent and fluorescent lights when leaving a space unoccupied; turn off high-intensity discharge lights when leaving a space unoccupied for 20 minutes or more (such as during lunch).

2.4 TURN OFF LIGHTS IN DAYLIGHTED SPACES

Daylighted spaces can be more energy efficient than electrically lighted spaces. This is because daylight has a light-to-heat efficacy that is better than electric lighting. However, the variability of daylighting requires careful consideration. A design which allows too much or too little daylight for lengthy periods of the day can drastically increase energy consumption.

Skylights are a good source of daylight in one story buildings. Daylight is also an effective source of ambient light for task-ambient lighting systems. Daylight is especially capable of reducing summer

peak electrical demand, since abundant daylight is available on such clear summer days. To be effective, daylighted spaces need good fenestration control and good electric lighting control.

2.5 LIGHTING MANAGEMENT CHECKLIST

The following checklist provides many options for accomplishing the four general lighting management measures. It is left to the energy conservation officer to determine which options are the most appropriate for his activity. Each option is discussed in more detail in Chapter 3.

LIGHTING MANAGEMENT CHECKLIST

Reduce Light Levels

- Disconnect unnecessary lights
- Install integral light switches in luminaires
- Install lower wattage lamps
- Install auxiliary impedance devices
- Reduce the voltage to the luminaire

Improve Lighting System Efficiency

- Install more efficient lamps
- Install more efficient ballasts
- Install more efficient lenses/luminaires
- Provide better maintenance
- Paint room surfaces with light colors
- Lower luminaire mounting height
- Implement task-ambient lighting concepts

Turn Off Lights in Unoccupied Spaces

- Publicize the fact that turning off lights is both energy saving and economically attractive
- Provide convenient wall switches
- Install time switches on bulletin boards, in closets, etc.
- Install pilot lights on infrequently used enclosed rooms

- Install time clocks or programmable controls for facilities on fixed schedules

- Install automatic occupancy sensors in public spaces

<u>Turn Off Lights in Daylighted Spaces</u>

- Provide convenient wall switches

- Control fenestration brightness

- Increase ground reflectance under windows

- Install skylights

- Remove paint from painted-over skylights

- Install automatic photoelectric controls

Chapter 3

IMPLEMENTATION

The options given in the checklist in Chapter 2.5 are expanded upon in this chapter. With this knowledge, the energy conservation officer will have a basic understanding of the various measures which can be implemented to improve the lighting management of the activity.

3.1 DISCONNECT UNNECESSARY LIGHTS

In overlighted spaces where light levels are twice as high as current standards:

- Disconnect or remove every other luminaire.

- Disconnect one of the two internal ballasts if the space contains four-lamp fluorescent luminaires.

In implementing the first action, ensure that load balance is maintained between phases. If luminaires are recircuited to maintain load balance, ensure that all feeder and branch circuits are not overloaded.

REMOVING LAMPS FROM BALLASTED LUMINAIRES WITHOUT DISCONNECTING THE BALLAST IS NOT RECOMMENDED. Besides wasting electricity, unloaded ballasts operate at a very low power factor, which could result in a power factor penalty from the local electric utility.

3.2 INSTALL INTEGRAL LIGHT SWITCHES

An integral lighting switch is simply a switch that is installed inside an individual fluorescent lighting fixture. Wall switches operate all the lights in a room, whereas integral lighting switches control each fixture independently. These switches are usually pull chain or toggle type switches. Figure 1 shows one way an integral lighting switch can be installed in a luminaire.

Although reduced light levels could also be achieved by removing lamps from the fixture, the integral lighting switch has the advantages of being convenient, eliminating the transporting and storage of lamps, and, most importantly, turning off the energy-consuming ballast.

Integral lighting switches can provide an effective means of converting uniform lighting systems to task-oriented lighting systems. Some restrictions are imposed by codes and standards that change from time-to-time, so always consult the latest editions before installing integral lighting switches.

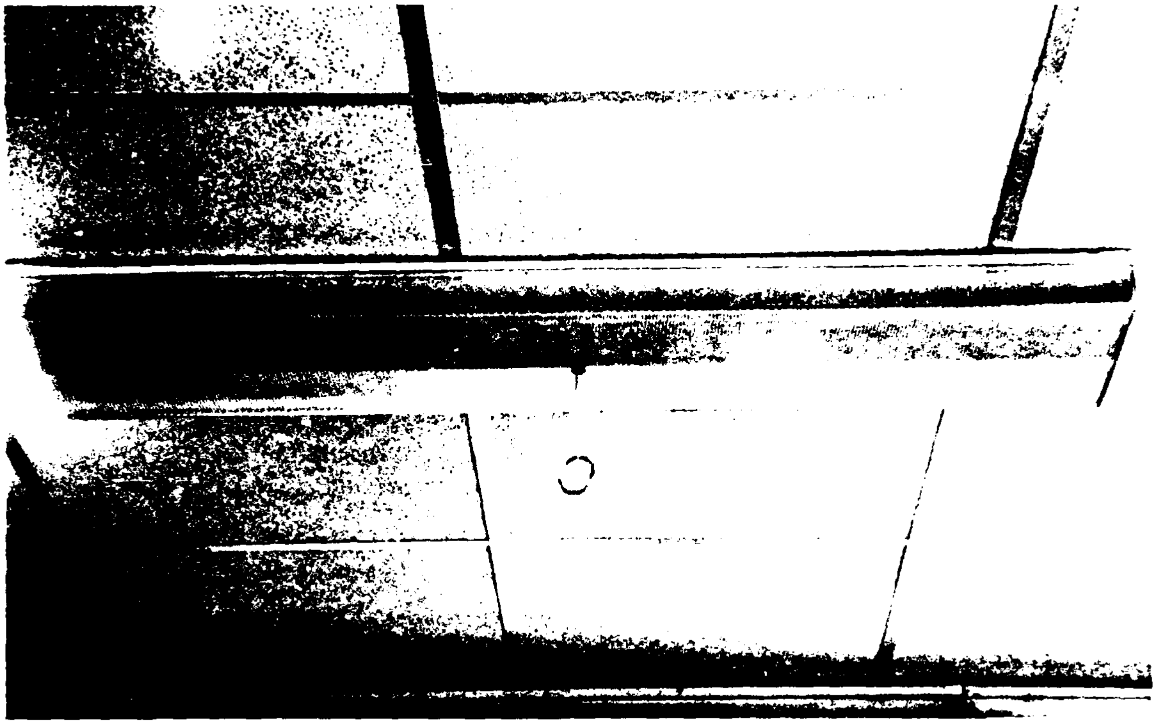

Figure 1. Integral lighting switch installed in a luminaire.

3.3 INSTALL LOWER WATTAGE LAMPS

Virtually all lamp manufacturers provide lower wattage lamps for energy savings. For fluorescent luminaires, 34/35-watt lamps replace 40-watt F40 lamps and 60-watt lamps replace 75-watt F96 lamps. The energy-saving fluorescent lamps are not as tolerant to environmental fluctuation, however. SUCH LAMPS SHOULD NOT BE USED WHERE THE AMBIENT TEMPERATURE DROPS BELOW 60°F. ALSO, THEY SHOULD NOT BE OPERATED ON DIMMING, LOW POWER FACTOR, EMERGENCY LIGHTING OR REDUCED CURRENT/REDUCED LIGHT OUTPUT BALLASTS, SINCE THIS MAY RESULT IN IMPROPER STARTING, LIGHT FLUCTUATION DURING OPERATION, AND SHORTENED LAMP LIFE.

3.4 INSTALL AUXILIARY IMPEDANCE DEVICES

These are devices designed for fluorescent luminaires. The devices augment the ballast impedance to provide reductions in light and power. Manufacturers often call these devices "watt reducers" or "energy savers" in their advertising. The light and power reductions are approximately proportional. Some of the devices are wired in series between the ballast and lamps; others snap into the lamp socket and the lamps snap into the auxiliary impedence devices. Devices are available that provide reductions of 33, 50, and 67%. Auxiliary impedance devices should be used only with standard 40- or 75-watt lamps, since energy-saving lamps should not be operated at reduced light output (Chapter 3.3). A partial list of manufacturers is given in Appendix B.

Energy buttons are small devices that fit into an incandescent socket. These devices are not recommended. A report funded by the Department of Energy at Lawrence Berkeley Laboratory concluded that "energy buttons drastically reduce light output and lamp efficacy, and are not cost effective even if lamps last fifty times longer and the labor cost for each change is fifteen dollars" (Ref 3).

3.5 REDUCE THE VOLTAGE TO THE LUMINAIRE

If incandescent lamps are burning out prematurely, a likely cause is slightly higher than normal voltage. Lamps rated at 120 volts will last for only half of rated life if operated at 125 volts but will last for twice rated life if operated at 115 volts. Alternatively, to get longer lamp life, purchase lamps at a higher rated voltage, such as 130 volts vice 120 volts.

Some manufacturers make electronic controls that reduce the voltage to fluorescent luminaires, causing a reduction in light output and power. Because lower wattage lamps should not be used in conjunction with these devices, and because of decreased system efficiencies, it is generally more cost effective to use lower wattage lamps or auxiliary impedance devices to achieve the necessary reduction in light levels.

3.6 INSTALL MORE EFFICIENT LAMPS

One of the most common energy conservation projects is the conversion of lighting systems to more efficient lamp types. Conversion from incandescent to fluorescent and from mercury vapor to high pressure sodium are two common examples. A sample Energy Technology Applications Program (ETAP) submittal for a lighting conversion is given in Appendix C.

Some characteristics of light sources are given in Table 3 of DM-4.4 (Ref 4) and recommended sources for specific task areas are given in Table 4 of DM-4.4. Section 4 of DM-4.4 contains these two tables and is reprinted in Appendix D.

Screw-in fluorescent replacement lamps are available to replace incandescent lamps (Figure 2). The fluorescent replacements have built-in ballasts and use only about one-third of the electricity of an equivalent incandescent lamp. However, since they are larger and quite a bit heavier than incandescent lamps, they cannot be used as universal replacements.

3.7 INSTALL MORE EFFICIENT BALLASTS

It is recommended that either solid state or premium magnetic ballasts be used as replacements for burned-out ballasts and specified for new construction. In purchasing new fixtures, some luminaire manufacturers may provide a "credit" for specifying certain types of high-efficiency ballasts, which may shorten payback periods to less than 1 year.

Solid state ballasts for high-intensity discharge lamps do not have as great an efficiency increase as do their fluorescent counterparts. Increased efficiencies typically range from 6 to 17%. However, the solid state ballasts do have much better voltage regulation than the magnetic ballasts, and the high frequency solid state ballast can

greatly reduce stroboscopic effect. Figure 3 shows the inside of a fluorescent solid state ballast. Premium fluorescent ballasts can provide energy savings up to 17%, and solid state fluorescent ballasts can provide energy savings up to 31%.

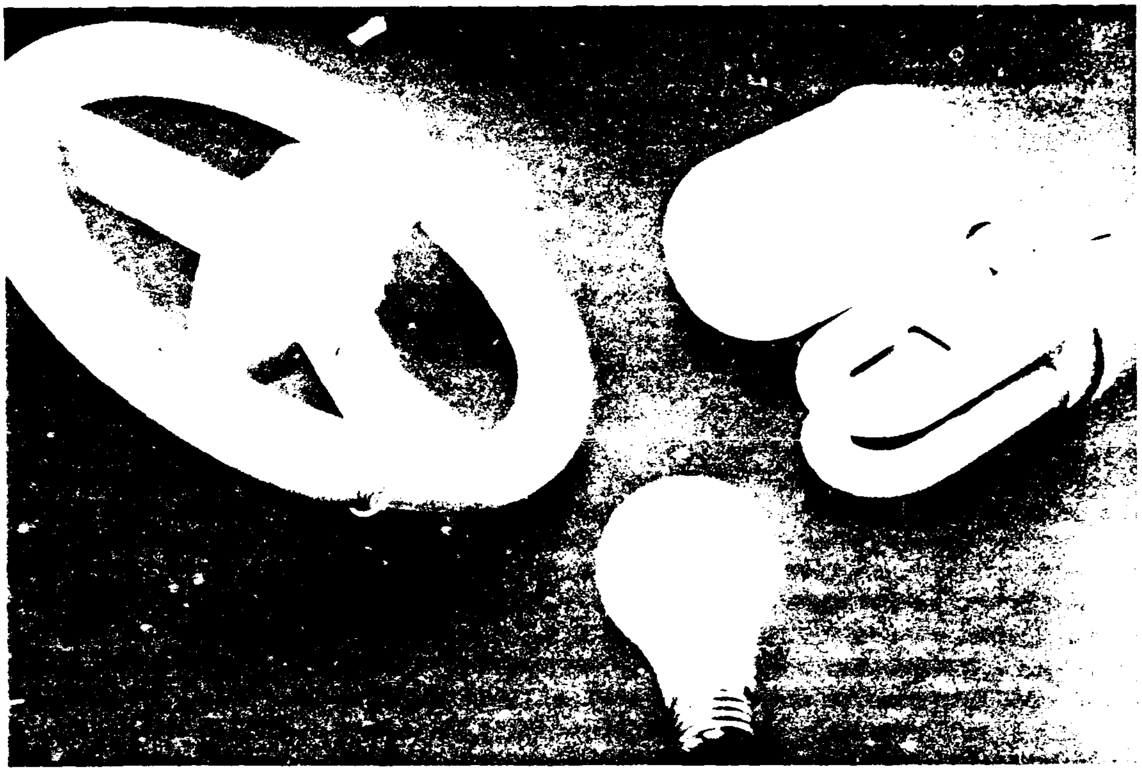

Figure 2. Screw-in fluorescent replacement lamps.

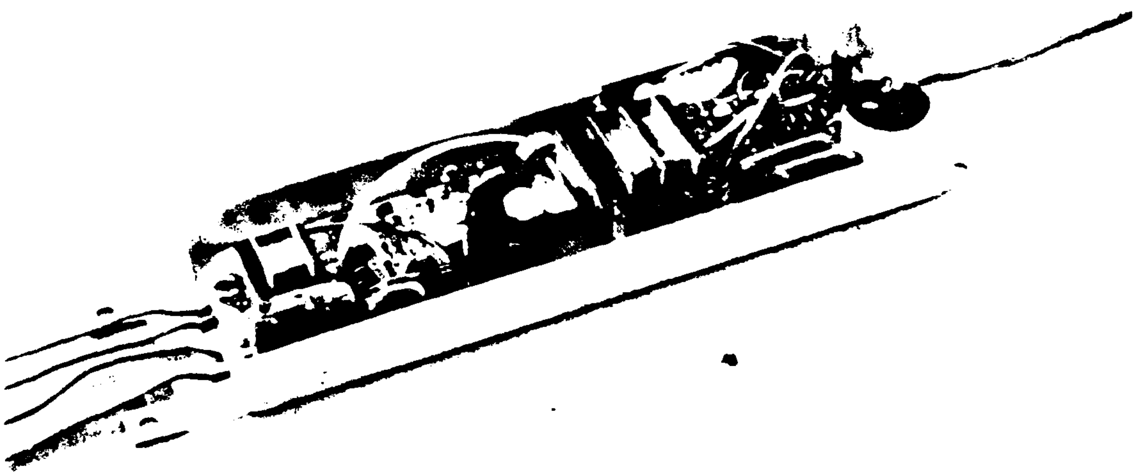

Figure 3. Inside of a solid state ballast.

3.8 INSTALL MORE EFFICIENT LENSES/LUMINAIRES

If installing new or replacement luminaires, choose luminaires from manufacturers' catalogs that give a high coefficient of utilization value. However, follow guidance given in DM-4.4 (Ref 4) regarding glare and spacing-to-mounting height so that glare and shadowing are not problems.

In existing spaces where it is desired to raise light levels, lenses can be removed from luminaires to increase efficiency. However, generally it is best to use lenses on luminaires to control glare. For some types of fixtures, replacement lenses may provide an increase in efficiency over existing lenses.

Many luminaires can be retrofitted with new reflecting surfaces. One product is designed for a four-lamp fixture with half the lamps removed. This retrofit provides slightly more light than most two-lamp luminaires.

3.9 PROVIDE BETTER MAINTENANCE

If periodic maintenance is not provided, 5 to 10 years after the installation of a lighting system light levels often drop to half of initial levels. Because deterioration of light levels from lamp aging and dirt accumulation is slow, it often goes unnoticed for many years. However, when employees notice that their work spaces are not as bright as a remodeled work space down the hall, they begin to complain of inadequate lighting. This situation can often be avoided if lighting systems are properly maintained through periodic cleaning and group relamping.

Some general rules-of-thumb for lighting maintenance are: (1) clean fixtures when light levels drop to 70% of initial levels, and (2) replace lamps at 70% of lamp life. Group replacement of lamps should be done concurrently with fixture cleaning. Additional information on lighting maintenance can be found in Chapter 4 of Reference 2.

3.10 PAINT ROOM SURFACES WITH LIGHT COLORS

Lighting in rooms with walls and ceilings painted with light (rather than dark) colors usually provides 10 to 20% more illumination on the work plane. One easy way to implement this is to use a color selection chart that is limited to the lighter colors. If using the Munsell system of color notation, the Munsell value should be between 7 and 8 for walls and 8 or above for ceilings.

The Munsell system is used to classify and specify color. Color is described by hue, value, and chroma. Hue is the name of the spectral color, value is a measure of the brilliance or amount of white, and chroma is a measure of the color purity. To specify a color under the Munsell system the hue, value, and chroma are given, for example, as 2.5G5/6, which is 2.5 green, a value of 5, and chroma of 6.

3.11 USE TASK-AMBIENT LIGHTING CONCEPTS

Task-ambient lighting simply means putting the light where it is needed. Figure 4 shows one way to do this: by lowering luminaire mounting height. In this case, one fixture directly over the work bench is more effective than a ceiling full of lights for providing task illumination.

Another important aspect is the direction of the light. Good lighting for office work should come from the sides or over the shoulders. The lighting in Figure 5 has adequate intensity but comes from the wrong direction. Light from the window is blocked by the body shadow when working. Most of the overhead lighting is directly in front of the desk, where it creates reflected glare (veiling reflections). The solution is to rearrange the lighting or, as shown in Figure 6, rearrange the furniture with respect to the lighting. With the new arrangement, light reaches the work area from the sides or over the shoulders, with very little light blocked by the body shadow or reflected off the desk from the reflected glare "offending zone."

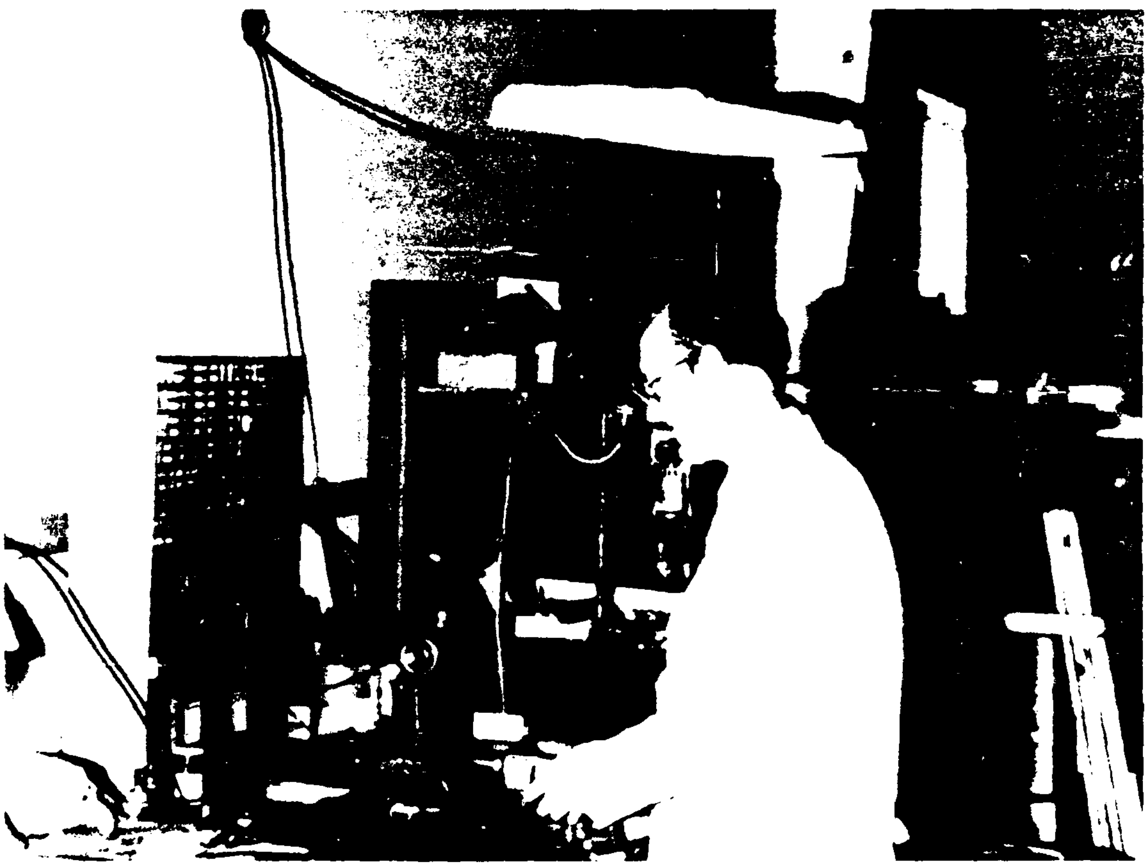

Figure 4. Placing a light fixture directly over the work bench is an example of task-ambient lighting.

Figure 5. Most of the lighting on the desk comes from the wrong direction.

Figure 6. Rearrangement of furniture with respect to the lighting to reduce reflected glare.

3.12 PROVIDE CONVENIENT WALL SWITCHES

Turning off lights in unoccupied rooms conserves electricity. Wall switches should be conveniently located adjacent to circulation areas. For spaces with multiple access joints, a low voltage control switching system may be an economical alternative. Where switches do not exist, consider adding them, particularly for the following areas:

- Spaces intermittently occupied
- Spaces in which only part of the area is occupied at any one time
- Areas where daylight is available for illumination

People should be encouraged to turn off lights when leaving a space. Not only does this save energy while the individual is gone, but upon returning if the minimum daylight illumination in the space is 30 footcandles, most people will not turn the lights on (unless they have been conditioned to <u>always</u> turn the lights on).

3.13 INSTALL TIME SWITCHES

Some lighting requirements have known short-time durations. Two examples would be the lighting in a janitor's closet and bulletin board lighting in a hallway. Time switches are ideal for these situations. One type of time switch looks and acts like a standard wall switch, except that it also automatically turns the lights off after a preset length of time.

3.14 INSTALL PILOT LIGHTS

Add pilot lights outside all rooms that are infrequently used and where there is no other external indication that lights have been left on. Pilot lights can be surface mounted or recessed and can usually be added in parallel with the circuit or load to be monitored. To conserve energy, consider use of neon pilot lights rather than incandescent pilot lights. Pilot lights should also be added to indicate remote loads that are energized. Place a notice next to the pilot light to indicate action to be taken, such as "If pilot light lit during daylight hours, turn switch off."

3.15 INSTALL TIME CLOCKS ON PROGRAMMABLE CONTROLS

Consider the use of time clocks or programmable controls for lights that can be operated from a schedule. For example, display lighting on food cases in commissaries and on merchandise displays in exchanges should only operate during regular store hours. Time clocks may be adequate for lights operating on simple schedules; programmable controls may be necessary for complex lighting patterns and complicated schedules.

3.16 CONTROL FENESTRATION BRIGHTNESS

Fenestration is any opening of a building (window, skylights, etc.). If interior surfaces near fenestration are painted a dark color, the luminance difference between the brightness of the fenestration and of the interior surface creates glare. An occupant of a space will reduce the glare by adjusting the fenestration control device-- usually venetian blinds on windows. But this reduces the daylight available. Painting window walls and other surfaces near the fenestration with light colors reduces the glare, since this reduces the brightness differences in the room. Thus, occupants will adjust blinds less often, providing more daylight into the space.

3.17 INCREASE GROUND REFLECTANCE UNDER WINDOWS

Daylight through windows consists of two components: a direct component from the sun and sky through the window to the work plane, and an indirect component from the sun and sky to the ground, through the window to the ceiling, and from the ceiling down to the work plane. The indirect component penetrates deeper into the room than the direct component and can provide good ambient lighting levels. Exterior landscaping adjacent to windows that incorporate higher reflectances (lighter colors), such as concrete, light decorative stones, etc., can provide substantially more indirect light than darker landscaping (such as asphalt, grass, etc.).

3.18 INSTALL SKYLIGHTS

Many single-story buildings are excellent candidates for skylights. A good time to install skylights is when reroofing; this minimizes leakage problems.

Skylights are often sized to provide the desired interior illumination level when the exterior horizontal daylight illumination is about 5,000 footcandles. This provides adequate interior illumination for sunny days during working hours for much of the year. To achieve good lighting uniformity, spacing between skylights should not exceed 1.4 times the ceiling height above the work plane.

Many metal buildings have shed roofs with 3- by 8-foot corrugated metal panels. Some of these panels can be replaced with matching fiberglass panels (Figure 7). Choose fiberglass that has a coating that screens out ultraviolet rays; this helps keep the fiberglass from losing its translucence.

If it gets too hot working under skylights in the summer, you do not have to paint them over and lose the benefits of natural lighting. Shade them with an overhang, which will reduce solar gain in the summer and increase it in the winter.

Figure 7. Skylighting can effectively replace electric lighting during the day.

3.19 INSTALL AUTOMATIC PHOTOELECTRIC CONTROLS

Automatic photoelectric controls can be used to turn off electric lights when sufficient daylight is present. On-off photoelectric controls are good for spaces where daylight is introduced through skylights or clerestories. On-off photoelectric controls should have an illumination deadband to avoid excessive cycling. When high-intensity discharge lights are controlled, the controller should also contain a time delay circuit (set to 20 minutes or longer).

Because of the daylighting gradient in rooms with windows, dimming photoelectric controls tend to provide a more even light distribution. On dimming systems, the mix of natural and electric light is more indistinguishable to the occupants when indirect luminaires or parabolic louvered direct luminaires are used. BECAUSE NONDIMMABLE SOLID STATE BALLASTS OFTEN PROVIDE AS MUCH ENERGY SAVINGS AS DIMMABLE MAGNETIC BALLASTS (AT ABOUT THE SAME CAPITAL EXPENSE), DIMMING PHOTOELECTRIC CONTROLS ARE NOT WIDELY USED.

3.20 INSTALL AUTOMATIC OCCUPANCY CONTROLS

For those spaces where light switches are not providing adequate control of the lights, an alternative is available -- electronic occupancy sensors that automatically turn off the lights after a room has been vacated. The most favorable applications are in the public areas of a building. Public areas include such spaces as conference rooms, reproduction rooms, restrooms, and corridors. Because no one usually knows who will be the last individual to leave a public area, the responsibility for turning off lights is not easily assigned.

Most electronic occupancy sensors sense the presence of persons in a space by detecting motion. The two common detection techniques used are ultrasonic and passive infrared. Sound detection is usually ineffective since such sensors are often triggered by noises outside the controlled space.

Chapter 4

AN INEXPENSIVE ACTION PLAN

The removal of lamps or luminaires is likely to result in some complaints, so it is worthwhile to plan a well-thought-out program rather than a shot-gun approach in which a certain percentage of lamps is removed. The action plan in this section describes a systematic way to provide the necessary quantity and quality of illumination desired in an inexpensive manner. This plan can often be accomplished within the existing Operation and Maintenance (O&M) budget.

4.1 INITIAL SURVEY

An initial survey is made to determine the present condition of the luminous environment. Field measurements apply only to the conditions that exist during the survey. It is therefore important to record a complete description of the surveyed areas, noting all the factors that can affect both the light output and electrical consumption of the installed lighting systems. The form given in Appendix E can assist in recording these factors. These factors include:

- Type of facility--Appendix A lists facility types, including a cross reference of DOD facilities to IES tables.
- Measured illuminance levels--For comparison to recommended illuminance levels.
- Lamp type--Such as F40T12 fluorescents.
- Luminaire number and type--Such as 16 two-lamp fixtures, IES type 35 (see Figure 9-12 of Reference 2 for IES types).
- Ballast type--Such as standard magnetic ballast.
- Voltage--Such as 118 volts measured at 1430 hours, 8 September 1983, at Panel LP-3.
- State of maintenance--Lamp age and last cleaning date if known; otherwise examine a typical fixture by removing the lense; checking the amount of dust or dirt on the lense and lamp; and checking for other signs of old age, such as blackened ends on fluorescent lamps. The fixture should be switched off during the examination. If the fixture appears to have been poorly maintained, clean the fixture and install new lamps. Turn on the lights and compare the clean relamped fixture with other

fixtures in the room. If the clean fixture is noticeably brighter, then the light output has increased at least by 30%, since the human eye has difficulty distinguishing brightness differences less than this.

- Interior surface reflectances--Usually recording just wall and ceiling reflectances is adequate, since the reflectance of the floor usually has little effect on the amount of light reaching a horizontal work plane. White ceilings usually have a reflectance of 70 to 80%. Wall reflectances can be determined as follows: Measure the illuminance on the wall by placing a light meter on the surface. Measure the exitance by turning the light meter around to face the wall and holding it away from the wall by 6 to 12 inches. The reflectance is the ratio of the exitance to the illuminance. Most walls will have a reflectance of 40 to 60%.

- Interior dimensions--Length and width of survey space, height of ceiling, and height of luminaires if different than ceiling height.

- Measuring equipment used in the survey--Model and serial number of instrumentation.

- Any unusual features--Does the surveyed space differ from typical spaces of this type in any manner? For example, the space may contain tall equipment that could cause shadowing problems if some lights are turned off.

4.2 PHOTOMETER ACCURACY

A photometer (light meter) is used to measure the illuminance level in a room. There are generally three things to consider when using a photometer: (1) calibrated accuracy, (2) cosine correction, and (3) color correction.

Calibrated accuracy is usually ±5% for laboratory photometers and ±10% for pocket photometers. The calibration of laboratory photometers should be checked every 6 months; pocket photometers should be checked once a year.

Cosine correction refers to whether the calibrated accuracy includes the effect of light falling on the photometer from various angles. Most photometers are cosine corrected over an angular range from 0 (normal to the photocell) to 80 degrees. An uncorrected meter may read as much as 50% below the true value.

Color correction refers to whether the calibrated accuracy includes the spectral distribution of light. Many pocket photometers are not color corrected. An uncorrected meter may be off by as much as 20%.

There are other factors as well that affect photometer accuracy, such as temperature, transient light effects, cyclical light effects, etc. The net effect is that one can only be reasonably confident of light level readings of ±10% using laboratory photometers and ±25% using pocket photometers. Further, this confidence can only be extended to meters which are well maintained and periodically calibrated.

4.3 ILLUMINANCE MEASUREMENTS

The only equipment necessary for illuminance measurements is a photometer. Measurement of the illuminance from electric lighting should be made either after dark or with daylight excluded from the interior. The illuminance should be measured at each work station (desk, bench, etc.), in a room with the photometer placed in the same place (horizontal or tilted) as the work. Measurements should be made with the worker in normal working position.

4.4 SOME THINGS TO OBSERVE

- Does the space seem to have a lot of lights on and few people? Are many work stations unoccupied? If so, make a note of it, and consider whether the space needs better types of occupancy controls.

- Does the space seem to have abundant daylight? Turn the lights off and take some illuminance measurements. How much daylight is there? If plenty, make a note of it, and consider whether the space needs better daylight controls or can make better use of the daylighting (e.g., task-ambient lighting, where the daylight provides the ambient light).

- Is the lighting system efficient? Could efficiency be improved by installing higher efficiency lamps? ballasts? luminaires? Are fixtures clean? Are surface reflectances high?

- Is there too much or too little light? Was adequate time given for the lights to stabilize after they were turned on? (This may take as long as 20 minutes.) Is the lighting arranged properly with respect to work stations, or is too much light in the body shadow or zone of reflected glare? Can lights be disconnected? Can lights have integral light switches installed?

4.5 THE ACTION PLAN

Based on the above observations and others like them, and the suggested alternatives offered in Chapter 3, one can begin to formulate an action plan. The suggested action plan described is in three parts: (1) no-cost options, (2) low-cost options, and (3) high-cost options.

4.5.1 No-Cost Options

Energy Drill. The energy drill has two purposes: (1) to make people aware of the need to conserve energy, and (2) to help break bad habits. Here is one activity's experience in conducting an energy drill (Ref 5):

NEWS RELEASE
PUBLIC AFFAIRS OFFICE
PACIFIC MISSILE TEST CENTER

The Pacific Missile Test Center, in cooperation with the Southern California Edison Company (SCE), monitored an electrical power reduction here September 15. SCE considers the power consumption at Point Mugu to be in excess of actual requirements. Navy power is therefore subject to unscheduled curtailment to meet the essential needs of all of their customers. Whenever SCE becomes aware of excessive loads, customers are notified within 2 to 24 hours of an impending reduction to prevent sequential or "rolling" blackouts.

Under such an emergency situation, SCE considers that Point Mugu should reduce its consumption by approximately 25%, some 2,688 kilowatts.

Previous load-shedding drills here showed no more than a reduction of 2,340 kilowatts when non-essential electrical devices, such as lights, blowers, fans, and etc., were turned off.

The September 15 half-hour drill here reduced total electrical demand from 12,393.4 kilowatts to 9,058.1 kilowatts within 13 minutes, and a few minutes later it dropped to a low point of 9,050.3 kilowatts.

Captain J.L. Godsey, PMTC's energy conservation officer, said the net reduction of 3,343.1 kilowatts was well in excess of expectations.

"Even more surprising than the results of the test itself is the fact that after the drill was over, the load increased only slightly and remained at least 2,000 kilowatts below our normal demand level for the rest of the day," he added. "Evidently there is a large load turned on each day that may not really be needed. This is something to consider when 'turning on' in the morning."

"That 2,000 kilowatts which was not used for the remainder of the day saved PMTC nearly 64 million Btus of energy and about $500. Also, 2,000 kilowatts represented 16.7% of our total average demand--and if it's wasted energy it can be saved. Yearly savings could add up to more than one million dollars."

"Be careful about the energy you use--use only what is actually needed and the results can be outstanding."

In his report on the results of the drill, Captain Godsey stated that each energy manager and load-shedding monitor, who were required to use their own judgment in determining what was non-essential, were to be congratulated for their part in helping PMTC far exceed the goal.

Note that after the drill was over, electrical demand remained well below normal. Other activities conducting energy drills have noted similar results. This is evidence that people are lax to turn off electrical loads when not needed. Having periodic energy drills helps to change people's habits, makes them more aware of energy conservation, and starts conditioning them to start turning off unnecessary electrical loads.

Publicity. Articles inserted into the Plan of the Day, newsletters, and the base newspaper all help to educate personnel to become more aware of energy conservation. Energy Awareness Week provides additional opportunities for publicity.

4.5.2 Low-Cost Options

Integral Light Switches. Based on the initial survey, decide which areas are suitable for installation of integral light switches. The three basic factors to look for are: (1) the space is overlighted, (2) employees work at specific work stations, and (3) there are 50 ft^2 of space or more per work station. This last factor is only a general guideline and assumes a fairly uniform distribution of work stations throughout the space, which may not be the case.

Delamping. Delamping is the process of removing lamps or, as is more commonly done, disconnecting the ballast. Information on delamping was given in Chapter 3.1.

Relamping and Cleaning. Installing integral light switches and disconnecting ballasts are electrician's work. Once they have completed their jobs, janitorial personnel can clean the fixtures and install new lamps. Based on the initial survey, the new lamps may be exact replacement or lower wattage lamps. Even for fluorescent fixtures, lamps are available that give about 30, 50, and 67% reductions of power and light, and can be used in spaces that are over-lighted.

4.5.3 High-Cost Options

High-cost options include most of the other items mentioned in Chapter 3. Implementation of the items requires Military Construction (MILCON), Energy Conservation Investment Program (ECIP), or Energy Technology Applications Program (ETAP) monies. One of the most common projects is the conversion to a more efficient lighting system. Appendix C shows a sample ETAP submittal for this type of project.

4.6 FOLLOW-UP SURVEY

After a space has had lighting modifications made for energy conservation, a follow-up survey is made to determine if appropriate light levels are available for tasks and if the lights are oriented correctly with respect to the work stations for good visibility. It is also useful to note the change in light levels and the appearance of the space and to estimate the energy savings achieved by the lighting modifications.

Chapter 5

THE INDEPENDENT TESTING LABORATORY REPORT

There are three types of literature that a manufacturer provides for a lighting energy saving product. First, every manufacturer provides sales literature that describes what the product does and where it can be bought. In addition, the sales literature usually also promotes all the advantages and benefits of using this device (but not any disadvantages). Secondly, the manufacturer may provide testimonials, in which users verify that the product indeed worked as claimed and that they could not be happier with the results. Testimonials can be misleading since all the before and after conditions are not known. For instance, a contractor may have installed an energy-saving device that reduced both light and power by 30%, but he also relamped and cleaned the lights, which brought the light output back up to the original level. The owner may then write a letter to the manufacturer of the energy-saving device saying how happy he is that the device is saving him 30% energy with no decrease in light levels! Lastly, the manufacturer will provide the independent testing laboratory (ITL) report on his product. To get this, though, the user must specifically ask the sales representative for the report.

The independent testing laboratory report should be used to qualify the claims made by the manufacturer. For instance, while a manufacturer may claim energy savings up to 40%, ITL tests may show a 20% saving. Does this mean the manufacturer has lied? Not necessarily. Electric consumption by lighting systems can vary because of a number of factors, including ambient temperature, voltage, and quality control. It would not be impossible for some users to get a 40% saving with only a 20% saving in the laboratory, but by the same token such a wide variance would also mean that some users probably would not get any savings. Because of this the ITL report can only be relied upon to give a measure of performance relative to other products under similar test conditions. The ITL report provides a better basis for making decisions for justifying ETAP and ECIP projects than sales literature or testimonials.

5.1 STANDARDS

If we are to rely upon ITL test reports, how can we have any assurance that various manufacturers' products were tested under similar test conditions? That is the purpose of standards. There are about 100 American National Standards Institute (ANSI) standards in the C78 series relating to lamps and about another 10 in the C82 series relating to lamp ballasts. Since most energy-saving products relate to fluorescent lighting systems, here are some of the more pertinent standards:

C78.1-1978 and C78.1a-1980	Fluorescent lamps, rapid start types
C78.2-1978	Fluorescent lamps, preheat types
C78.3-1978	Fluorescent lamps, instant start and cold cathode types
C78.375-1973	Fluorescent lamps, guide for electrical measurements of
C82.1-1977(R1982)	Fluorescent lamp ballasts, specifications for
C82.2-1983	Fluorescent lamps ballasts, methods of measurements of
C82.3-1983	Fluorescent lamp reference ballasts, specifications for

In addition, the Illuminating Engineering Society (IES) of North America provides a number of standards relating to lighting measurement, including:

LM-9	IES approved method for electrical and photometric measurement of fluorescent lamps
LM-15	IES guide for reporting general lighting equipment engineering data
LM-40	IES approved method for life performance testing of fluorescent lamps
LM-41	IES approved method for photometric testing of indoor fluorescent luminaires
LM-56	IES approved guide for the photometric and thermal testing of air-cooled heat transfer luminaires

One could ask, "If a product is new and unique, then obviously no standard exists for it. What good are all these other standards?" These standards ensure the reliable operation of a standard lighting system Although there may not be a standard for an auxiliary impedance device, for instance, that device is used with the existing fluorescent lamp and ballast. The data within the ITL report should indicate that the lamps and ballast still operate within the ANSI standards even with the energy-saving device installed. Otherwise, the report should flag those areas of operation that are outside the ANSI standard and discuss the possible consequences on lamp and ballast operation, reliability, and maintainability.

5.2 IMPORTANT TESTS FOR FLUORESCENT LAMPS

Here from the ANSI standards are certain tests that are made on rapid-start fluorescent lighting systems and the reasons for the tests (Ref 6 and 7).

Test	Reason for Test
Root Mean Squared (RMS) voltage (voltage measured by AC volt-meters) across lamp terminals under an open circuit	Indicates if there is sufficient voltage to ignite the normal commercial lamp for which the ballast is rated.
Voltage crest factor (under an open circuit)	Indicates if voltage waveshape (due to a sharp spike) could damage lamp cathodes, causing short lamp life.
Terminal voltage to starting aid under an open circuit	Indicates if there is adequate peak voltage to the starting aid (ground) to ignite the lamp.
Relative light output (minimum ratio)	Indicates the amount of light emitted from test lamps operated with commercial ballasts, relative to that emitted while these lamps are operated on standard reference ballasts.
Light output regulation	Indicates if the ballast will operate its lamp load within the specified percentage limits if input voltage changes.
Lamp current	Indicates if the ballast will regulate current supplied to lamps below a specified value. Too high lamp current can damage lamps and shorten life.
Current crest factor	Indicates if the ballast is generating a waveshape (peak spike) that may cause abnormal wear to the lamp.
Lamp power (minimum ratio)	Indicates the power supplied to test lamps by a commercial ballast to the power supplied to test lamps by a reference ballast.
Lamp power regulation	Indicates if the ballast will operate its lamp load within specified percent ratios of wattage, if input wattage changes.

Test	Reason for Test
Power factor	Indicates whether or not the ballast will require high-input current. If the power factor is low, the ballast will draw more amperes than a ballast with a high power factor. This can result in higher wiring and operating costs.
Cathode measurement under simulated load	Indicates if the lamp cathodes are provided with adequate power to heat cathodes for proper lamp starting. Insufficient (or excessive) heating causes reduced lamp life.
Heating	Indicates if the ballast will operate below maximum temperature limits specified by ANSI safety requirements. Abnormally high heat will cause reduced ballast life.

If the lamps and ballasts operate within the ANSI standards, then lamp and ballast life should not be shortened. Some manufacaturers mistakenly claim that their energy-saving product will prolong lamp life simply because it reduces the power to the lamp. Note the cathode measurement under simulated load test: if lamp cathodes are either insufficiently heated (reduced power) or excessively heated (increased power) lamp life is reduced. The only way lamp life can be determined for sure is to run a life cycle test in accordance with IES standard LM-40. This is a test that generally requires several years to run since there is no approved accelerated lamp life test. Because most manufacturers do not want to wait this long, they do not run this test. Therefore, many claim for extended lamp life are unfounded.

5.3 START SMALL TO GAIN CONFIDENCE IN A PRODUCT

Ocassionally a product will have a problem that no one expected and that does not show up until a number of units have been installed. For example, one Navy activity lost two-thirds of its solid state fluorescent ballasts (40 out of 60) following a power outage. Naval Civil Engineering Laboratory (NCEL) tests showed that the ballast failed to withstand transients in accordance with Institute of Electrical and Electronic Engineers (IEEE) standard 587-1980, category A. Accordingly, NCEL recommended to field activities (Ref 8) that they specify compliance with IEEE standard 5871980, category A, for normal and common mode transients. Thus, a wise course of action with most products that are new on the market is to install only a limited number until you are satisfied that the product operates reliably. If the activity in the example had installed 6,000 ballasts, such a massive failure could have hampered its mission. If there are any significant problems with a product, they will usually show up within the first year of operation.

5.4 CONCLUSION

When interested in an energy-saving lighting product, be sure to request the independent testing laboratory report. Check to see that the normal ANSI tests have been made and that the lighting system components operate within the ANSI specifications. Use the results of the tests (conducted under ANSI or IES standard conditions) as a basis for comparing alternative modifications to your lighting systems.

Chapter 6

REFERENCES

1. Department of Defense. DOD 4270.1-M: Department of Defense Construction Criteria Manual. Washington, D.C., Jan 1983.

2. Illuminating Engineering Society. IES lighting handbook, edited by J.E. Kaufman. New York, N.Y., 1981.

3. Department of Energy. Contract Report LBL-10789: Cost effectiveness of long life incandescent lamps and energy buttons, by R. Verderber and O. Morse. Berkeley, Calif., Lawrence Berkeley Laboratory, Apr 1980. (Contract No. W-7405-ENG-48)

4. Naval Facilities Engineering Command. Design Manual DM-4.4: Electrical utilization systems. Alexandria, Va., 1979.

5. Pacific Missile Test Center. News release. Point Mugu, Calif., Oct 1981.

6. Certified Ballast Manufacturers Association. CBM News Bulletin, no. 67, p. 2. Cleveland, Ohio.

7. __________. CBM News Bulletin, no. 68, p. 1. Cleveland, Ohio.

8. Naval Civil Engineering Laboratory. Techdata Sheet 83-15: High efficiency fluorescent ballasts, by W. Pierpoint. Port Hueneme, Calif., Jul 1983.

Appendix A

EXCERPT FROM CHAPTER 7, DOD 4270.1-M (Ref 1)

Chapter 7. Electrical Criteria

7-1 LIGHTING:

7-1.1 DESIGN REQUIREMENTS: The design of interior, exterior, and sports lighting shall be in accordance with fundamentals and recommendations of the IES Lighting Handbook (Reference 7(a)), published by the Illuminating Engineering Society, subject to the modifications and clarifications noted in Sections 7-1.2 through 7-1.6.

7-1.2 LIGHTING INTENSITIES FOR FACILITIES: Maintained lighting intensities shall conform to those recommended in the current edition of the IES Lighting Handbook except as modified herein. The IES intensities were published as minimums for specific tasks. However, they will be considered maximum design levels not to be changed significantly except in areas designed for an integrated air-conditioning and lighting system. The recommended intensities required for the predominant specific visual tasks in an area may be provided by the general illumination for the area. However, maintained general illumination will not exceed 75 footcandles in any area, unless otherwise indicated herein. Where fluorescent general lighting levels exceed 50 footcandles in air-conditioned areas, an integrated air-conditioning and lighting system shall be evaluated (see Chapter 8), and lighting fixtures shall meet the necessary requirements.

A. Conservation Requirements. Normally, general illumination levels in administrative areas shall not exceed 50 footcandles at work stations, 30 footcandles in work areas, and 10 footcandles in nonworking areas. These illumination levels, in conjunction with energy conservation, shall be obtained by the most life-cycle cost-effective techniques including, but not limited to the following:

1. Multiple switching of multilamp fixtures and/or multiple switching of fixture groups in large rooms, to permit lights to be turned off at unoccupied work stations and installing 2 lamps in 4 lamp fixtures having integral toggle switches capable of disconnecting one ballast (2 lamps) from the supply source.

2. Time clock and/or photoelectric control of general indoor and outdoor lighting.

3. Multilevel switched ballasts to provide nonuniform general lighting.

4. More efficient lighting sources, fixtures, and lamps.

5. Grid-type ceilings with the capability of interchanging relocatable panels and lighting fixtures without rewiring. (This type of ceiling will provide flexibility to accommodate changes in functional requirements of occupants.)

6. Lower wattage lamps (35 watt versus 40 watt fluorescent lamps).

B. Special Requirements. If an intensity greater than 75 foot-candles is required for a particular task, it will be provided by localized (supplementary) lighting. The ratios between general and supplementary illumination shall not exceed those recommended by IES. Supplementary lighting normally will be provided by the user of the facility. However, power for such lighting shall be provided.

C. Environmental Factors. The finish and color of surrounding surfaces, equipment and furniture shall be selected for reduced glare, increase light use and acceptable brightness balance. Lighting equipment and layout shall be coordinated with other facilities to prevent interferences and to promote good appearance.

D. Cross Reference of DOD Facilities to IES Tables. In some instances the names and functions of facilities used by DOD are not the same as names and functions of similar facilities given in the IES tables of recommended levels of illumination. For purposes of comparison, the following cross references are given in Table 7-1, below.

Table 7-1. DOD-IES Cross Reference of Facility

Designation of DOD Facility Name or Function	Designation of Facility Name or Function in IES Tables
Administrative Areas	Officer, Drafting, Conference, and Accounting Rooms
Auto Maintenance Shops	Garages, Service Stations
Barracks and BOQ's	Hotels
Base Exchanges	Stores
Chapels	Churches and Synagogues
Classroom Buildings	Schools
Dining Facilities	Food Service Facilities
Guard Houses, Brigs	Municipal Buildings - Fire and Police
Parking for Military Vehicles (with minor repair area)	Parking Areas, Service Stations
Service Clubs	Applicable Areas of Auditoriums, Food Service Facilities, Offices, Schools, Stores
Warehouses	Storage Rooms or Warehouses

E. Medical and Dental Facility Illumination. Lighting intensities for medical and dental facilities shall conform to the IES recommendations with the exceptions listed in Tables 7-2 and 7-5, below.

Table 7-2. Illumination in Medical and Dental Facilities

Area	Footcandle Intensity[1]
Anesthesia and Preparation Room	30
Central Sterile Supply	50
Fracture Room	50
Linen Room	30
Exits, at Floor Level	5
Corridors in Patient Care Areas	30
Corridors, Other	10

[1]Supplementary lighting and general illumination in specialized areas, where needed for rooms and spaces in medical and dental facilities, will be prescribed by Surgeon General of the using Service.

F. Hanger Illumination. The general maintained illumination level of hangers shall not exceed 75 footcandles.

G. Warehouse Illumination. The general illumination level in warehouses shall not exceed the values listed in Table 7-3, measured 4 feet from the floor.

Table 7-3. Illumination in Warehouse

Type of Warehousing	Footcandle Intensity
Inactive	5
Active-bulk	10*
Rack	20
Bin	5**

Table 7-3. (continued)

Type of Warehousing	Footcandle Intensity
Mechanical Material Handling:	
a. Control Centers and Stations	30
b. Loading and Unloading Areas	20
c. Accumulation Conveyor Lines (unmanned)	10

*Main aisles may be lighted to 15 footcandles.
**Specialized lighting designed to illuminate the bins as required is to be provided by the user.

H. <u>Exterior Sports Illumination</u>. Outdoor sports lighting shall conform to the classifications stated in the IES Lighting Handbook as listed in Table 7-4.

Table 7-4. IES Sport Classification

Sport	IES Classification
Baseball	Municipal and Semiprofessional
Softball	Industrial League
Football	Class III or IV
Other	Recreational

I. <u>Illumination in Functional Areas of Other Facilities</u>. The general illumination level in other functional areas shall not exceed the intensities indicated in Table 7-5.

Table 7-5. Illumination of Function Areas of Other Facilities

Area	Footcandle Intensity
Accounting Rooms	75
Auditoriums	20
Cafeterias	25
Computer Rooms	50

Table 7-5. (continued)

Area	Footcandle Intensity
Conference Rooms	30
Corridors	10
Drafting Rooms	75
Elevator Machine Rooms	15
Emergency Generator Rooms	15
Garage Entrance	30
Garage Driving and Parking	5
General Office Space	50
Janitor's Closets	5
Kitchens	70
Lobbies	15
Lounges	15
Mechanical Rooms	15
Parking Lots	0.5
Stairways	20
Storage Rooms	75
Switchgear Rooms	15
Toilets	20
Transformer Vaults	15

J. Special Facility Illumination. Where fluorescent or high intensity discharge lighting is prohibited and the required intensity exceeds 30 footcandles, the general lighting system should be designed for incandescent lighting of 30 footcandles with supplementary incandescent lighting for specific tasks where required.

7-1.3 EMERGENCY LIGHTING: Emergency lighting systems shall be provided in accordance with the requirements of NFPA 101 (Reference (7b)). In facilities with standby electric power systems, provisions shall be made

to transfer the exit lighting system to the standby generating source. Emergency supplementary incandescent lighting of 2 footcandles along aisles and walkways in high bay areas where high intensity discharge lighting is used shall be provided. In buildings with large electrical loads, full consideration shall be given to possible economies from the use of higher voltages and/or frequencies for the lighting system (see Sections 7-2.2.A and 7-2.2.B).

7-1.4 EXIT LIGHTING: Exit lighting and exit signs shall conform to the NFPA 101. Exits, exterior steps and ramps shall be adequately lighted to prevent accidents. Separate lighting shall not be provided if street or other permanent lighting gives at least one footcandle at the exit, steps or ramp.

7-1.5 MAINTENANCE AREA LIGHTING: Crawl spaces with utility services, interior utility tunnels, and walk-in pipe chases shall be lighted as required (approximately one footcandle) for the safety of maintenance personnel. Switches for these lights shall be equipped with pilot lights and located in areas that are normally occupied. Keyed switches may be used if required. Receptacles shall be located at reasonable intervals in these maintenance areas for temporary work lights and portable tools.

7-1.6 STREET, AREA, AND SECURITY LIGHTING:

A. Street and Area Lighting: Streets, parking areas, and walks in residential, administrative, and community support areas shall be lighted to provide safe vehicular and pedestrian circulation. Lights shall be at street intersections, and between intersections at a spacing of approximately 150-200 feet. Walks and steps in public walks, not adjacent to streets shall be separately lighted. Control of exterior street and area lighting normally will be by automatic timers and/or photoelectric cells.

B. Security Lighting. Since most security lighting must meet specialized requirements, it will be designed to meet the users needs using the most energy-efficient lighting practicable.

7-1.7 INSTALLATION REQUIREMENTS:

A. Barracks. In open sleeping areas, low-level night lights shall be located so that beds are not directly illuminated. Occupants' rooms may have a nightlight or a secondary room light of low illumination located to facilitate moving about during night hours without disturbance to sleeping occupants. Occupants' rooms shall have one or more switches conveniently located inside the room to control general room illumination. Barracks with open sleeping areas or partial partitions shall have separate switches for each subarea in an easily accessible location. Switches shall be located so that access is not blocked by double-decked beds or lockers. Luminaires used in open area barracks, or in barracks with partial partitions, shall direct light into the area served by each switch so that spillage into adjacent areas is a minimum.

B. Communications Facilities. General lighting shall be arranged parallel to equipment aisles wherever possible, to provide maximum illumination and to avoid overhead cable trays. In areas where manual equipment is used, operator efficiency must be assured by carefully positioning luminaires to avoid glare and excessive light on the face of the equipment, while maintaining a reasonable light level on the horizontal surface. Supplementary lighting may be provided over work benches in maintenance and test areas.

C. Hospitals. Where practicable, general lighting in medical, surgical and clinical areas shall use recessed luminaires having flush glass or plastic panels to minimize dust collection. Luminaires in neuropsychiatric patient areas shall have impact resistant tempered glass lenses, and those located in bedrooms shall incorporate a low wattage nightlight, separately switched. Over each bed in patients' bedrooms (except neuropsychiatric) a wall-mounted luminaire having a locally controlled direct lighting component, and an indirect lighting component supplied from a separate lamp for general illumination in the vicinity of the bed shall be provided. A low wattage, shielded, wall-mounted nightlight shall be provided in patients' rooms of 4 beds or less, and for larger rooms an additional light shall be provided for each group of 4 beds. Incandescent luminaires shall be used in rooms where equipment sensitive to radio frequency radiation is operated or adequate RFI shielding shall be installed on fluorescent units.

D. Officers' Clubs, NCO Clubs and Service Clubs. Ballrooms and lounges serving multiple functions shall have the general lighting arranged for multiple switch control so that different intensities may be selected. Small hand-operated dimmers may be used in lieu of multiple switch control provided that costs are comparable. Facilities shall be provided to permit connections of portable spots, floods or accent lights as required. For the general lighting, ballrooms may be provided with motor operated dimmers controlled from the bandstand and main entrance.

E. Training Facilities. Classroom lighting immediately in front of the lecture platform may be controlled from a point convenient to the speaker's platform and also at the entrance. Auditorium lighting may be controlled by motor operated dimmers from the platform (off stage) and the main entrance to facilitate use of audio-visual aids. Lighting may also be controlled from those points by switches. Minimum lighting shall be provided so that notes may be taken during the use of visual aids. Indoor rifle ranges shall be provided with indirect or low brightness luminaires in the firing area to avoid undesirable reflections. Target luminaires and those in the firing lanes shall be protected by shields from stray bullets.

F. Warehouses. Lighting arrangements shall suit the warehousing techniques employed. For pallet storage general lighting may be confined to the aisles with supplementary lighting units provided in the aisles and directed to illuminate the storage areas. The latter shall be controlled separately from the aisle lighting. Trolley-mounted luminaires may be employed where shifting of the luminaires is practicable. Lights shall be controlled from panelboards except that

lights at aisle intersections and intermediate key points may be remotely controlled by low voltage switches from multiple points to permit passage of security guards and access to panelboards. Provision shall be made at loading doors for supplementary or portable lighting for the illumination of truck or rail car interiors.

G. Weapons Systems Control Area. Lighting shall be specially engineered. Low levels of lighting may be required to permit observation of luminous panels without reflected glare or undesirable contrasts in brightness. Separately controlled luminaires shall be provided for normal illumination operations and cleaning purposes.

7-1.8 LUMINAIRES: Generally, luminaires shall be standard commercial type, and shall conform to the Underwriter's Laboratories, Inc., Standard for Electric Lighting Fixtures, Publication No. 57 (Reference (7c)).

A. Specialized Luminaires. Special luminaires may be provided when required by the seeking task or architectural treatment of the building. For specific areas, explosion-proof, dust-tight, dust-ignition proof, or weatherproof luminaires shall be provided in accordance with the requirements of NFPA 70, National Electrical Code (Reference (7d)).

B. Architectural Considerations. Luminaires shall be integrated with the architecture of the room or area. The correct use of luminaires is of special importance in large rooms or areas with high and/or sloping ceilings. Therefore, the type and hanging of luminaires shall ensure that the desired architectural effect and function of the space are not impaired. Where facilities are modified for different uses, luminaires shall be installed at the most economical height and manner to provide for the new functions.

7-2 INTERIOR ELECTRICAL FACILITIES:

7-2.1 CODES: Electric lighting and power systems within buildings and facilities shall be installed in accordance with the latest revisions to the applicable National Fire Protection Association Codes.

7-2.2 SYSTEM CHARACTERISTICS: System characteristics shall provide for most efficient and economical distribution of energy.

A. Voltages. Voltages shall be of the highest order consistent with the load served. Single phase 120/240 or three phase 208Y/120 volts shall generally be used to serve combined incandescent and fluorescent and high intensity discharge or lighting loads, and small power loads. Where practical and economically feasible, a three phase 480Y/277 volt system shall be used. Other voltages may be used where required.

B. Frequencies. Where other than 60 Hz power is supplied (e.g., 50 Hz), the frequency supplied shall be used where practical. Where frequencies other than that locally available are required for technical purposes, frequency conversion equipment may be provided, or if

economically justified, generation equipment may be installed. Such equipment normally will be provided by the facility user. For special facilities where in-house prime generation must be provided and gas turbines are used, consideration shall be given to higher frequency generation (e.g., 800 Hz) to achieve greater efficiency from fluorescent lighting and to simplify the speed reduction from turbine to generator.

7-2.3 DESIGN GUIDANCE: The design analysis of electrical systems shall use good procedures and shall show all calculations used in determining capacities of electrical systems. Methods and tabulations used in sizing conductors, conduit, protective devices and other equipment required to complete a system shall be included. All calculations shall be clearly shown so that any changes that become necessary may be made efficiently. When tables used in the design are taken from publications, the title, source, and date of the publication shall be plainly indicated. The model number and manufacturer of each major piece of equipment on which space allocation was determined shall be indicated in the analysis.

7-2.4 ALTERNATIVE POWER SUPPLY: For facilities having emergency generating systems with capacities in excess of 200 kilowatts, or where central supervisory, monitoring and control systems exist or are planned for an installation, an economic analysis shall be performed, and, where cost effective, installation of a demand controller considered. Cost effectiveness will be based upon the practicality of reducing demand charges by peak-shaving with the emergency generator(s) normally provided for such facilities as hospitals and communications installations.

7-2.5 SPECIFICATIONS: Materials and equipment shall conform to Federal Specifications or commercial standards as promulgated by such organizations as the Underwriters Laboratories, Incorporated; the National Electrical Manufacturers Association; the Institute of Electrical and Electronic Engineers; and the American National Standards Institute.

7-2.6 WIRING:

A. General. In general, wiring shall consist of insulated conductors installed in rigid conduit, intermediate metal conduit (IMC), or electrical metallic tubing (EMT). Aluminum conduit shall not be used underground or embedded in concrete or masonry. Metal enclosed feeder or plug-in busways or surface metal raceways may be used where required. In frame and hollow block construction above finished grade, flexible metallic armored or nonmetallic sheathed cables may be provided for concealed branch circuits installed in areas not subject to mechanical injury. Conductors shall be copper, except that aluminum may be used in sizes equivalent to No. 6 AWG copper and larger.

B. Underfloor Conduits and Cable Space. In administrative areas, underfloor ducts for electrical wiring and telephones shall be used only to eliminate safety hazards in large open bays. Underfloor electrical ducts or cable space may be used in EDP or ADP machine rooms and in research facilities where anticipated changes or large equipment can justify their use.

C. Receptacles. Receptacles installed on 15- and 20-ampere branch circuits shall be the grounding type with the grounding pole identified.

7-2.7 MAINTENANCE AND OPERATION: Clear space shall be provided around switchboards, panelboards, transformers, switches, and controllers for normal maintenance and operation as required by NFPA.

Appendix B

PARTIAL LIST OF MANUFACTURERS

Auxiliary Impedance Devices

GTE Sylvania Thrift Mate
Sylvania Lighting Center
Danvers, MA 01923
(617) 777-1900

Remtec Systems
1341 West 130th Street
Gardena, CA 90247
(800) 421-2662

Development Sciences, Inc.
P.O. Box 1264
City of Industry, CA 91749
(213) 330-6865

Integral Light Switches

McGill Manufacturing Company
Electrical Division
1550 N. Campbell Street
Valparaiso, IN 46383
(219) 464-4911

Leviton Manufacturing Company
59-25 Little Neck Pkwy.
Little Neck, NY 11362
(212) 229-4040

Sylvania Wiring Devices, Inc.
Box 591
720 Monmouth Street
Trenton, NJ 08604
(609) 392-3141

Solid State Ballasts

Litton Industries
1124 E. Franklin Street
P.O. Box 1147
Huntington, IN 46750
(800) 348-5032

Electronic Ballast Technology, Inc.
20695 South Western Ave., Suite 105
Torrance, CA 90501
(213) 618-8733

Fyrnetics Inc.
1021 Davis Road
Elgin, IL 60120
(312) 742-0282

Occupancy Controls

Tishman Research Company
3150 Republic Boulevard North, Suite 5
Toledo, OH 43615
(419) 841-666

Novitas, Inc.
1523 26th Street
Santa Monica, CA 90404
(213) 829-1822

Colorado Electro-Optics, Inc.
2200 Central Avenue
Boulder, CO 80301
(303) 494-3200

Photoelectric Controls

Precision Multiple Controls, Inc.
231 Greenwood Avenue
Midland Park, NJ 07423
(201) 444-8410

Lite-Miser Ltd.
1550 South Sunkist, Unit E
Anaheim, CA 92805
(714) 634-4218

Controlled Environment System, Inc.
P.O. Box 1190-B
Rockville, MD 20850
(301) 424-4570

Lutron Electronics Co., Inc.
205G Suter Road
Coopersburg, PA 18036
(800) 523-9466

Time Switch

Enertron, Inc.
1100 Wicomico Street
Baltimore, MD 21230
(301) 837-1837

Screw In Fluorescent Replacement Lamps

North American Philips Corp.
255 West Carob Street
Compton, CA 90220
(213) 605-1724

General Electric Company
P.O. Box 2494
Cleveland, OH 44108
(216) 266-4264

Retrofit Reflectors

Maximum Technology
60 Industrial Way
Brisbane, CA 94005
(415) 468-2560

Diamond Energy Controls
2400 Main Street
Irvine, CA 92714
(714) 474-1181

Appendix C

SAMPLE ETAP SUBMITTAL FOR LIGHTING CONVERSION

Calculations Analysis

Lighting System: Acoustic Sound Range Laboratory, Bldg. 26

Naval Ship Repair Facility Guam

Scope: Replace 21 existing 300-W incandescent lighting fixtures with fluorescent type (energy-efficient ballast and two energy-efficient 60-W lamps).

Lamp (60-W) Lumens (mean): 5,500 lumens
Lamps and Ballast Input Watts: 113 W
Area of room (18 ft x 36 ft): 648 ft^2 (SF)
Required Lighting Level: 50 footcandles
Coefficient of Utilization (CU): 0.50
Maintenance Factor (MF): 0.75
Operation: Monday through Friday
9 hr/day x 260 days/yr = 2,340 hr

$$\text{No. of Fixtures} = \frac{\text{FC x SF}}{\text{No. lamps/fixture x lumens/lamp x CU x MF}}$$

$$= \frac{50 \times 648}{2 \times 5{,}500 \times 0.50 \times 0.75} = 7.85$$

$$= 8$$

Energy Savings

Lighting

Existing

kW-hr = 21 x 300 W x 2,340 hr/yr

= 14,742 kW-hr/yr

Proposed

kW-hr = 8 x 113 W x 2,340 hr/yr

= 2,115 kW-hr/yr

Savings = 14,742 kW-hr - 2,115 kW-hr = 12,627 kW-hr/yr

Air Conditioning

Savings

12,627 kW-hr = 43,095,951 Btu/yr

Reduction in energy required for cooling:

$$= \frac{43{,}095{,}951 \text{ Btu/yr x ton}}{12{,}000 \text{ BTU/H}} \text{ x } \frac{1.5 \text{ kW}}{\text{Ton}} \text{ x } 0.8 \text{ (load factor)}$$

= 4,310 kW-hr/yr

Total Energy Savings = 12,627 + 4,310

= 16,937 kW-hr/yr or 196 MBtu/yr

Other Savings: (Lamp Replacement)

Lamp Life

300-W incandescent: 750 hr

60-W fluorescent (with electronic ballast) = 20,000 hr

Existing

$$\text{Lamp replacements} = \frac{21 \text{ x } 2{,}340 \text{ hr/yr}}{750 \text{ hr}} = 66 \text{ lamps/yr}$$

Cost = 66 lamps/yr [$1.40/lamp (material) + $6.00/lamp (labor)]

= $488/yr

Proposed

$$\text{Lamp replacements} = \frac{16 \text{ x } 2{,}340 \text{ hr/yr}}{20{,}000 \text{ hr}} = 2 \text{ lamps/yr}$$

Cost = 2 lamps/yr [$4.50/lamp (material) + $6.00/lamp (labor)]

= $21/year

Savings

$488/yr - $21/yr = $467/yr

NAVFAC 11013/7 (1-78)
Supersedes NAVDOCKS 2417 and 2417A

COST ESTIMATE

DATE PREPARED: 4 JAN 1983

SHEET 1 OF 1

ACTIVITY AND LOCATION: SRF GUAM, M.I.

CONSTRUCTION CONTRACT NO

IDENTIFICATION NUMBER

ESTIMATED BY: B. Y. WONG

CATEGORY CODE NUMBER

PROJECT TITLE: LIGHTING SYSTEMS - ETAP

STATUS OF DESIGN: ☐ PED ☐ 30% ☐ 100% ☐ FINAL ☐ Other (Specify) ____

JOB ORDER NUMBER

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NUMBER	UNIT	UNIT COST	TOTAL	UNIT COST	TOTAL	UNIT COST	TOTAL
1. Remove Existing Fixtures	21	EA			24	504	24	$ 504
2. Fluorescent Fixtures w/2 60W Lamps	8	EA	125	1000	100	800	225	1,800
3. Circuit Modification, Conduit & Wiring	1	LS						1,000
SUBTOTAL								$3,304
Escalated to FY84 $3304 X 1.06 X 1.06								$3,712
Contingency 10%								371
SIOH 5.5%								204
SUBTOTAL (Rounded)								$4,300
Design 6% of $4287								260
TOTAL								$4,560

S/N 0105-LF-010-1335

ETAP ECONOMIC ANALYSIS

ACTIVITY & LOCATION SRF Guam, M.I. PROJECT NO.
TITLE OF PROJECT Lighting Systems DATE 4 January 1983

INVESTMENT

1. PROJECT COSTS (Economic life of 25 years)
   a. Construction cost escalated to FY84 .... $ 4,300
   b. Design cost.. $ 260
   c. Total Project Cost (a + b)........................ $ 4,560

SAVINGS

2. ANNUAL ELECTRICITY SAVINGS: KWH: 16,937
   a. Equivalent energy: KWH X 0.0116 = 196 MBTU:
   b. Cost per KWH at end of program year.................. $ .145
   c. First year annual dollar savings (KWH x b)............ $ 2,456
   d. ETAP present worth factor............................. 18.049
   e. Discounted savings (c x d)............................ $ 44,326

3. ANNUAL ENERGY SAVINGS TYPE: ______ MBTUs: ______
   a. Cost per MBTU at end of program year.................. $ ______
   b. First year annual dollar savings...................... $ ______
   c. ETAP present worth factor............................. ______
   d. Discounted savings (b x c)............................ $ ______

4. ANNUAL ENERGY SAVINGS TYPE: ______ MBTUs: ______
   a. Cost per MBTU at end of program year.................. $ ______
   b. First year annual dollar savings...................... $ ______
   c. ETAP present worth factor............................. ______
   d. Discounted savings (b x c)............................ $ ______

5. ANNUAL OTHER-THAN-ENERGY SAVINGS (OR COSTS)
   a. Labor... $ 384
   b. Material and Other.................................... $ 83
   c. Total (a + b)... $ 467
   d. ETAP present worth factor............................. 9.524
   e. Discounted savings (Costs)(c x d)..................... $ 4,448

6. TOTAL FIRST YEAR ANNUAL SAVINGS (2c+3b+4b+5c)................ $ 2,923

7. TOTAL DISCOUNTED SAVINGS (2e+3d+4d+5e)...................... $ 48,774

8. TOTAL MBTU SAVINGS (2a + 3 + 4).............................. 196

COST ESCALATION

Current rates	*ELEC	$ 0.128	X 1.13	x	x	=	$ 0.145
as of	*OIL	$	X	x	x	=	$
	*GAS	$	X	x	x	=	$
Dec , 1982	*	$	X	x	x	=	$

SUMMARY

9. DISCOUNTED SAVINGS/INVESTMENT RATIO (Line 7/1c)............ 10.7
10. SIMPLE PAYBACK PERIOD (1c/Line 6)........................... 1.6 YRS
11. E/C RATIO (Line 8/Line 1c/1000)............................. 43.0

SPECIAL PROJECT REQUEST
NAVFAC 11014/64 (REV. 5-74)
Supersedes NAVFAC 9-11014/64 (11-68)
S/N 0105-LF-003-4730

STEP TWO SUBMISSION

1. ACTIVITY SNDL NO.	ACTIVITY NAME AND LOCATION	DATE SUBMITTED
N62586	U.S. Naval Ship Repair Facility, Guam	

2. PROJECT NO.	TITLE
	Lighting Systems

3. TYPE

a. [ ] MAINT/REPAIR b. [X] MINOR CONSTRUCTION/ALTERATION c. [ ] AIR CONDITIONING [ ] EQUIPMENT INSTALLATION

4. DESCRIBE AND STATE FUNCTION OF FACILITY

Building 26 is one story, reinforced concrete block structure. The Acoustic Lab is a research facility located on a promontory used to analyze sound signals from the ocean.

a. PROPERTY RECORD CARD NO.: 200195
b. NAVY CATEGORY CODE: 15935
c. BLDG OR STRUCTURE NO: 26

5. WHAT IS THE EFFECT OF THIS PROJECT ON THE MISSION OF THE ACTIVITY?

This project will reduce energy consumption by 16,937 kWh/yr. Energy to cost ratio is 43.0 MBTU/$1000 and the simple payback period is 1.6 years.

6. THE REQUIREMENT FOR THE FACILITY IS BASED ON:

a. [ ] A CHANGE IN MISSION b. [X] FULL TIME CONTINUING NEED c. [ ] 3 TO 5 YEAR NEED d. [ ] LESS THAN 3 YEARS' NEED e. [ ] CURRENTLY REQUIRED LESS THAN 50% OF TIME f. [ ] RESERVED FOR FUTURE REQUIREMENTS

7a. EST. FUNDED COST	b. EST. PROJECT COST	c. EST. PLANNING COST	d. TOTAL FUNDS REQUESTED	e. EST. FACIL. REPL. COST
$ 4,560	$ 4,300	$ 260	$ 4,560	$

8. DATE FACILITY CONSTRUCTED: 1968

9. IS FACILITY ON AN APPROVED BASIC FACILITY REQUIREMENTS LIST? If "NO," how was need determined?

[X] YES [ ] NO

10. IS PROJECT LISTED ON ANNUAL INSPECTION SUMMARY? If answer is "NO," and AIS is applicable, explain exclusion.

[X] YES [ ] NO [ ] N.A.

11. DESCRIBE CONDITION TO BE CORRECTED, OR PROBLEM TO BE SOLVED WITH PROPOSED SOLUTION. Attach additional description if necessary. ONE PAGE ONLY

Presently, the building is lit with incandescent lights. This project will provide a more energy efficient fluorescent lighting to reduce energy consumption.

12. WHY IS THE PROPOSED SOLUTION BEST — AND WHAT ALTERNATIVES WERE CONSIDERED?

This project will use high efficiency fluorescent lighting and improve lighting distribution and reduce energy consumption.

13. WERE ANY NON-NAVY EXPERTS INVITED TO REVIEW THIS PROBLEM AND THIS SOLUTION? Explain effect on solution.

a. [ ] YES b. [X] NO

14. HAS EFD DESIGN DIVISION REVIEWED SOLUTION? a. [ ] YES b. [X] NO

15. CAN ANOTHER FACILITY BE ECONOMICALLY ADAPTED FOR THIS FUNCTION? a. [ ] YES b. [X] NO

16. CAN PROJECT BE FUNDED IN PHASES? How? How many?

a. [ ] YES b. [X] NO

17. THIS PROJECT IS THE RESULT OF

a. [ ] INADEQUATE MAINTENANCE b. [ ] FACILITY AGE c. [ ] DEFICIENT CONSTR d. [ ] DEFICIENT DESIGN e. [X] OTHER Energy Conservation

18. HAS THIS SPECIFIC PROBLEM BEEN CORRECTED PREVIOUSLY?

a. [ ] YES b. [X] NO When?

HOW LONG WILL PROPOSED CORRECTIVE ACTION LAST? 25 YEARS

19. ARE COMPONENTS BEING INCREASED IN SIZE OR CAPACITY? *Explain the difference, including cost.*

a. [ ] YES b. [X] NO

20. ARE MATERIALS PROPOSED FOR USE THE SAME AS THOSE EXISTING? *If "NO," explain the difference including cost.*

a. [ ] YES b. [X] NO

Fluorescent lighting will be used to replace incandescent lighting.

21. PROJECT IS PLANNED TO BE ACCOMPLISHED BY

a. [ ] STATION LABOR b. [X] CONTRACT

22. HAS A PROJECT EVER BEEN SUBMITTED FOR THE REPLACEMENT OF THIS OR SIMILAR FACILITIES? *Check and explain if "YES."*

a. [ ] YES b. [X] NO *When?*

23. ANTICIPATED SAVINGS IF PROJECT IS DONE THIS YEAR AS COMPARED TO A DEFERRAL OF ONE YEAR.

PROBABLE INCREASE IN PROJECT COST FOR ANY JUSTIFIABLE REASON	REDUCTION IN CURRENT MAINT. COST	REDUCTION IN CURRENT OPERATIONS COST
$ 410	$ 445	$ 2,371

JUSTIFY ANY SAVINGS INDICATED

Increase in project cost due to inflation. Energy saving will result in reduction of operating cost and lamp replacement.

WHAT IS PAY BACK PERIOD OF PROJECT? *(in years)* 1.5

WILL ACCOMPLISHMENT GENERATE REQUIREMENTS FOR ADDITIONAL M&O FUNDS OR PERSONNEL? a. [X] NO b. [ ] YES *Est. Ann.*

24. WHAT WOULD BE THE EFFECT OF DEFERRING THE PROJECT ONE YEAR?

Energy savings not realized.

*25. IF THE PROJECT IS NOT ACCOMPLISHED NOW, IN HOW MANY YEARS WILL THERE BE SERIOUS DAMAGE TO THE FACILITY AND/OR ITS CONTENTS OR IMPAIRMENT TO ESSENTIAL OPERATIONS? *Explain, include cost value to facility and/or contents.*

YEARS BEFORE SERIOUS DAMAGE OCCURS N/A.

*26. HAS THE REDUCED UTILIZATION OF THIS SPECIFIC FACILITY AFFECTED A LARGE FACILITY SYSTEM OPERATION? *Explain.*

a. [ ] YES b. [X] NO BY HOW MUCH? ____ %

27. ARE THERE ANY OTHER FACTORS INVOLVED? *Check and explain.*

a. [ ] MORALE b. [ ] HEALTH c. [ ] PUBLIC RELATIONS d. [ ] SAFETY e. [ ] FIRE PROTECTION f. [ ] SECURITY g. [X] OTHER

Energy Conservation

28. CERTIFICATION BY RESPONSIBLE OFFICER AT ACTIVITY: I am personally cognizant of the need for, the essentuality of, and the proposed method of accomplishment of this project and certify that the above information is correct, and that this project meets all criteria specified in OPNAVINST 11010.20 and subsequent changes thereto.

SIGNATURE	TITLE	DATE

29. EFD TECHNICAL VALIDATION *(if required) (see para 7303, OPNAVINST 11010.20C)*

SIGNATURE	TITLE	DATE

ENCLOSURES

a. [X] ENGINEERING EST. *(NAVFAC 2417)* b. [X] LOCATION PLAN(S) c. [ ] DRAWINGS d. [ ] PHOTOGRAPHS

**NOT applicable to Minor Construction, Alterations, or Equipment Installation*

NAVFAC 11014/84 (REV. 8-74)
Sheet 2 of 2

S/N 0105-LF-003-4230

Appendix D

EXCERPT FROM SECTION 4, DM-4.4 (Ref 4)

4. LIGHTING. The design of interior lighting systems and lighting intensities shall be in accordance with DOD 4270.1-M and the IES Lighting Handbook. For lighting levels, luminaire types for special areas and particular requirements, consult criteria for the specific facility.

a. Architectural Requirements. Lighting systems shall be coordinated with building designs for aesthetic and decorative effects, within the limits of visibility, visual comfort, economics and energy conservation.

b. Design Analysis. Lighting calculations shall adhere to the established procedures of the IES as set forth in the IES Lighting Handbook and IES Recommended Practices.

(1) Usual Illumination Analyses. For general applications, average illumination may be calculated using room cavity ratios and luminaire coefficients of utilization (zonal-cavity method).

(2) Special Computer Analyses. When comprehensive lighting studies are required to determine alternative lighting sources for large multi-roomed buildings or average to minimum illumination (point-by-point method), it may be necessary to run a computer analysis using NAVFAC programs.

(a) CEL-1 program. The CEL-1 program can analyze the following quantities:

(i) Illumination (natural lighting and artificial lighting)

(ii) Equivalent Sphere Illumination (ESI)

(iii) Visual comfort probability (VCP)

(iv) Wall luminances

(v) Electric consumption with automatic lighting controls

(b) E-6801 (LIGHT) program. The E-6801 program is suitable for determining illumination for large multi-roomed buildings.

(c) RELAMP program. Economics (luminous flux per uniform annual cost) for any lighting system may be optimized using the RELAMP program.

(d) SELFDOC System. A listing and description of available NAVFAC computer programs can be found in the computer aided design (CAD) SELFDOC system.

c. Visibility. Luminaire placement and candlepower distribution shall be chosen to minimize veiling reflections. Veiling reflections reduce the contrast of the components of the task and make seeing the task more difficult. Light coming over the workers' shoulders or from the sides generally produces better visibility than light coming from the front of the workers (offending zone). An analysis of ESI can be made when the specifics of the task are known, along with a knowledge of the task background and luminaire candlepower distribution and location in relation to the task. Generally such detailed analyses will be unnecessary unless specifically required.

d. Visual Comfort. Luminaire placement, candlepower distribution, and luminance ratios shall be chosen to minimize discomfort glare. Discomfort glare is produced by high brightness within the field of view. Visual comfort may be determined by making a VCP analysis, or by requiring that the luminaire have a minimum VCP of 70 and also meet the other luminance requirements for visual comfort required in the IES handbook.

e. Economics. For a large building, a comprehensive lighting study may be required from an economic viewpoint to aid in the selection of lighting sources and sizes of lamps. When studying alternatives, consider the initial investment, life span of the installation, energy expense, cost of replacing light sources at the end of effective life, and cleaning cost. Life-cycle costs shall be calculated in accordance with NAVFAC P-442, Economic Analysis Handbook. Selection of the most economical alternative shall be based on the maximum luminous flux (lumens) per uniform annual cost.

f. Energy Conservation. Means shall be provided to reduce general lighting operating intensities in accordance with the criteria of DOD 4270.1-M. These methods, fully covered by DOD 4270.1-M, include reduction by manually turning off selected luminaires using multiple switching circuits, and time or photoelectric control. Multiple switching circuits can utilize alternative switching of luminaires, inboard-outboard switching of four-tube fluorescent luminaires, local switching for task control, perimeter lighting control adjacent to glassed areas so as to take advantage of daylight, and use of SCR dimmers where economically feasible. Other methods include use of lower wattage lamps, or provision of ceiling construction which easily accommodates luminaire relocation. Energy conservation methods shall apply not only to administrative areas, but to all areas with illumination levels of 30 footcandles (30 dekalux) and above.

g. Lighting Source. When selecting lighting sources for interior systems, the most important aspect is the characteristics of th' source; however, also consider stroboscopic effect, radio interference, chromacity, and color rendition.

(1) Characteristics. Characteristics of light sources are shown in Table 3. The light source used should be the most energy conserving consistent with usage.

Table 3. Characteristics of Light Sources

Characteristics	High Intensity Discharge[1]			Fluorescent	Incandescent
	HPS	Metal Halide	Mercury Vapor		
Luminous efficacy (lumens/watt)[2]	70-125	65-100	30-50	55-65	15-25
Lumen maintenance	Good	Fair	Poor	Fair	Good
Lamp life (1,000 hours)	20-24	7.5-15	24	12-20	1-2.5
Lamp life[3] (years)	5-6	2-4	6	3-5	0.25-0.65
Start-up time (minutes)	2-4	3-5	5-7	---	---
Restrike time (minutes)	1	10-15	3-6	---	---
Color rendition	Fair	Good	Fair	Good	Good
Neutral surface color effect	Yellow-pink	White	White	Blue-white	Yellow-white

[1] Incandescent safety lighting is required in large areas or corridors. For areas where HPS fixtures are used, consider installing emergency light sets with a 5 minute time delay off to take care of the restrike or start-up time. For other HID lamps, longer time delays should be provided.

[2] Ballast losses are included.

[3] Computer based on 4,000 burning hours a year.

(2) Recommended Sources for Specific Task Areas. Table 4 shows recommended usage for specific task areas.

Table 4. Recommended Sources for Specific Task Areas

Task Area	Light Source
Office areas	Fluorescent[1]
Low-bay shop areas[2]	Fluorescent
Medium-and-high-bay shop areas[3]	High-pressure sodium[4]

[1]In areas with ceilings 10 feet (3 meters) or lower, use recessed fixtures with prismatic diffusing panels.

[2]Ceilings less than 15 feet (4.5 meters).

[3]Ceilings of 15 feet (4.5 meters) or higher.

[4]In areas with ceilings of less than 25 feet (7.5 meters), use 250 watt or smaller lamps. For ceiling of 25 feet (7.5 meters) or higher, use 400 watt lamps.

(3) Additional Considerations.

(a) Color Rendition. Unless there is a need for color matching, color rendition need not be considered. Where the color rendition of high-pressure sodium (HPS) lamps is unacceptable, metal halide lamps should be used in preference to mercury vapor lamps, if the available lamp wattage is suitable for the area.

(b) Chromacity. Chromacity within areas should always be considered. Once the adaptation has been made to a lighting system of any color temperature, user acceptance is greater when another color source is not introduced. Thus in a shop area using HPS lamps, the small office and toilet spaces commonly associated with the area should also use HPS lamps. If fluorescent lamps must be used in such an area, they should be the warm-white type. The surrounding color environment (painted walls, ceiling, and floor) shall be compatible with the chromacity of the selected source.

(c) Radio Frequency Interference. Fluorescent fixtures can be provided with shielded enclosures and foltered ballasts for use in areas where radio frequency interference (see DM-12) must be minimized (for example in an Instrument Calibration Shielded Room).

(d) Stroboscopic Effect. Except for high speed photography and other rare situations, stroboscopic effect generally will not be a problem. Flicker Index has been established by the IES as the measure of stroboscopic effect.

(e) Sources Not Recommended. Incandescent lighting should not be used, unless no other type of light source is suitable for the special conditions encountered. It has been included in Table 3 only for comparison purposes. Aesthetic reasons are not acceptable for using a source of such low luminous efficacy. Low-pressure sodium lighting is not included as the color is monochromatic and therefore normally is not suitable for general use.

h. Luminaires. In general, luminaires shall conform to NAVFAC TS-16510; Lighting, Interior. Particular effort should be made to reduce the number of luminaire types in any one facility, building, or project, so that the number of spare part replacement required for maintenance will be kept to an absolute minimum. Luminaires, not otherwise covered by this specification, shall be manufacturers' standard types.

(1) Architectural Criteria. The aesthetics of the luminaire shall be compatible with the area in which it is located.

(2) Classification. Explosion-proof and weatherproof lighting fixtures shall be provided when required for conformance to the National Electric Code. To be suitable for damp location, wet locations, or as an enclosed and gasketed fixture, luminaires must be UL listed as meeting the requirements of UL 57, Electric Lighting Fixtures. To be suitable for hazardous locations, luminaires must be UL listed as meeting the requirements of UL 844, Electric Lighting Fixtures for Use in Hazardous Locations.

(3) Maintenance. Ease of servicing luminaires must be considered in the design process. For lighting fixtures installed in areas where it is difficult and hazardous to relamp fixtures when using ladders (for example, ceiling fixtures in stairwells), consider the use of open bottom fixture enclosures that provide access for relamping with a lamp changes, or mount fixtures on walls.

(4) High Intensity Discharge Lighting. High intensity discharge (HID) lighting should be used to illuminate large, high-bay areas.

(a) Efficiency. Luminaire efficiency should not be less than 70%.

(b) Spacing-to-Mounting Height (S/MH) Ratio. The spacing to mounting height ratio of the luminaire should be not less than 1.3 nor more than 2.0 to provide both uniformity of illumination and sufficient lighting on vertical surfaces. Wattage of lamps should not be increased due to this wide distribution over that indicated in Table 4. Closer spacing will result in an overlap of beam patterns. In the event of lamp burnout, the loss of illumination will not be as severe, and the vertical lighting will be greater than would be the case from a luminaire with a more concentrating distribution of light. IES requires that the distance from the working plane to the bottom of the luminaires should be used as the mounting height in calculating the S/MH ratio.

(c) Glare. Not more than 10% of the light should be emitted from the 60 to 90° zone for reasonable freedom from glare. Low brightness diffusers are generally not necessary as HID luminaires are limited to shop areas with ceilings of 15 feet and higher. However, where used in associated small office and toilet spaces with lower ceilings, a diffuser should be used for mounting heights less than 15 feet (4.5 meters) above the finished floor.

(d) Noise Ratings. At the present time, no industry noise rating has been given to HID ballasts. For most shop areas, the ambient sound level will mask the ballast hum.

Appendix E

LIGHTING SURVEY FORM

LIGHTING SURVEY FORM

Date: ______________

Buidling No. ______________ Panel No. ______________ Photometer Model ______________

Type of Facility ______________ Voltage ______________ Serial No. ______________

Last Calibrated ______________

Room Number	Light Level	Room Dimensions			Room Reflectances			Number of Fixtures	Lamps per Fixture	Fixture Type	Comments on Maintenance Condition, Daylighting Controls, Occupancy Controls
		L	W	H	F	W	C				